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# Ethylenediamine assisted growth of single crystal tellurium channels

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**Abstract**

Single crystal tellurium channels have been synthesized through the ethylenediamine assisted hydrothermal treatment method. The products were characterized by SEM, TEM, SAED, HRTEM, EDS and XRD measurements. The results show that the as-prepared tellurium channels have the 1D channel like nanostructures with the width about 600 nm in diameter. It is also shown that the tellurium channels with the hexagonal phase crystallinity grow preferentially along the [001] direction.


*Keywords:* Crystal structure; Nanomaterials; Electron microscopy

## 1. Introduction

Recently great efforts have been made to synthesize one-dimensional (1D) nanostructures (such as nanowires, nanorods or nanotubes) due to their potential use as active components or interconnects in fabricating nano-scale electronic, optical, optoelectronic, electrochemical and electromechanical devices [1–4]. A number of methods have been developed to fabricate and assemble 1D nanostructures, including arc discharge [5], laser ablation [3,6], template-assisted synthesis [7,8] and other methods [9–11].

Tellurium is of interest in many applications due to its useful and intensive properties: for example, photoconductivity; catalytic activity toward hydration or oxidation reactions; and high piezoelectric, thermoelectric, or non-linear optical response [12–14]. In addition, the unique highly anisotropic crystal structures of trigonal tellurium consisting of helical chains of covalently bound atoms, which are in turn bound together through van der waals into a hexagonal lattice, make it inherent chirality, as well as a strong tendency toward 1D growth. As Xia et al. have demonstrated in the synthesis of $RuSe_2$ and $Pd_{17}Se_{15}$ nanotubes, the availability of 1D tellurium nanostructures may also be able to bring in new types of applications or enhance the performance of the currently existing applications for its readily reacting with other elements to generate a wealth of functional materials such as $Bi_2Ti_3$, ZnTe and CdTe [15,16].

Many efforts have been made to synthesize the 1D tellurium nanostructures (such as nanorods, nanowires or nanotubes) [14,17–19]. Among those methods, the 1D tellurium nanostructures were always synthesized by the reduction of higher valence tellurium compounds such as $TeO_2$ [19] and tellurate [18]. Here, we report a simple method to directly convert the stock tellurium materials into the 1D channel like tellurium nanostructures. This method involves the hydrothermal process during which the solid tellurium is dissolved in the ethylenediamine aqueous and then directly recrystallized into the 1D channel like tellurium nanostructures with the assistance of ethylenediamine. The growth mechanism of this directly

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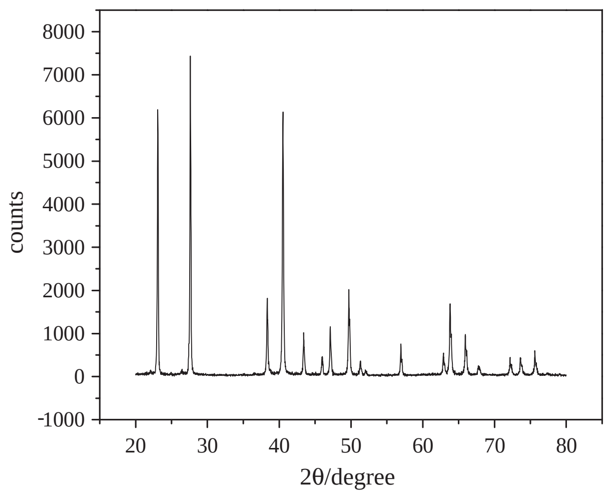


Fig. 1. The XRD pattern of the tellurium channels.

conversion process may be different from that in other procedures as well as the reduction of higher valence tellurium compounds. What is more, to the best of our knowledge, this channel like single crystal tellurium (which is something like a split half part of a tube) has not been reported before.

## 2. Experimental

The reaction was carried out in a 50 ml capacity Teflon-lined stainless steel autoclave. All chemicals were used as received. In a typical procedure, 1.5 g tellurium was suspended in 30 ml water through supersonic treatment, then 10 ml ethylenediamine was mixed with the solution uniformly. After that, the mixed solution was transferred to a Teflon-lined autoclave which was then sealed into a stainless-steel tank and heated at 160 °C for 24 h. After cooling down to room temperature, a gray precipitate was collected, washed with water several times and dried in air at 60 °C. Through such a process, the 1D channel like tellurium product was finally produced.

The crystallinity and purity (phase and composition) of the as-prepared products were characterized with X-ray powder diffraction (XRD, X'pert MPD Philips X-ray diffractometer) and energy dispersive X-ray (EDX) measurements. The morphologies and micro-or nanostructures of the tellurium channels were further characterized with a JEM-200EX transmission electron microscopy and a JEM-2010 high resolution transmission electron microscopy. SEM images were taken with a SIRION 100 scan electron microscopy.

## 3. Results and discussion

Fig. 1 shows the X-ray diffraction pattern of the as-prepared samples. The peak positions and their relative intensities are very consistent with a hexagonal phase of tellurium (space group: $P3_121(152)$). The lattice constants calculated from the diffraction pattern are $\alpha$ = 4.4512, $\beta$ = 5.9177, compatible with the literature values of $\alpha$ = 0.4458 nm, $\beta$ = 0.5927 nm (JCPDS 36-1452). The XRD pattern indicates that pure tellurium products were obtained by this method. This crystal structure is a very stable crystalline form of tellurium, which consists of parallel spiral chains of tellurium atoms terminating at the corners and center of regular hexagon. The bonding within the chains is much stronger than the bonding between the chains [12,14].

The morphologies of the prepared samples were investigated by transmission electron microscopy (TEM) and scanning electron microscopy (SEM) (Fig. 2). In the TEM images, it was found that the samples were 1D hollow nanostructures which are something like tubes

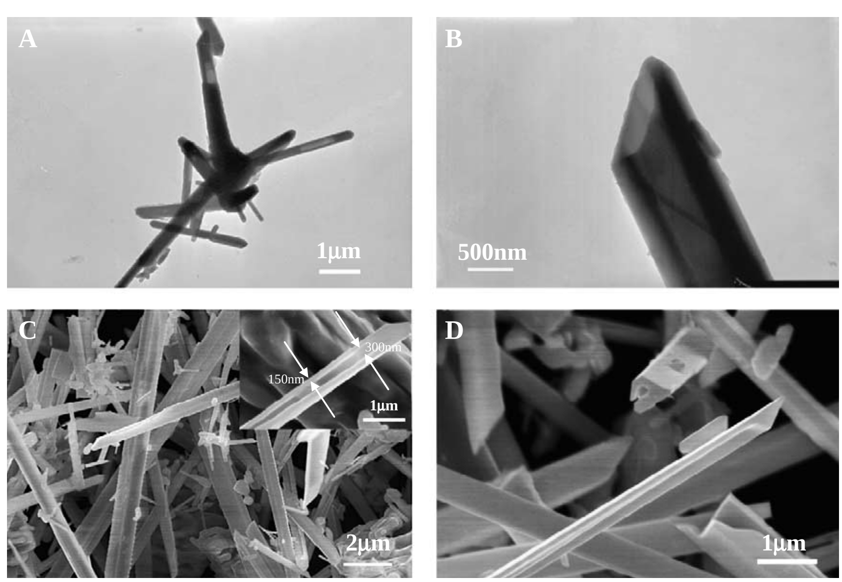


Fig. 2. The TEM and SEM images of the tellurium channels. A) TEM image, B) enlarged TEM image of the single tellurium channel, C) and D) SEM image of the tellurium channels. Inset in C) is the SEM image of the single tellurium channel.